IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: GUGLER et al. Group Art Unit: 1762

Serial No.: 10/660,399 Examiner: K. Bareford

Filed: September 10, 2003

For: METHOD AND DEVICE FOR COATING A MOVING WEB

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

STATEMENT BY DR. JAKOB KUHN

Sir:

I, Dr. Jakob Kuhn, am responsible for patent related matters for ILFORD Imaging Switzerland GmbH, the assignee of the above-identified application. The application was filed in the English language in the United States Patent & Trademark Office ("PTO") on September 10, 2003 and claims priority to European Patent Application 02405783.8 filed September 10, 2002 ("the priority application").

I prepared the English translation of the above-identified priority application and I certify that the translation is a true and exact translation to the best of my knowledge and belief.

Date: February 27, 2006

JAKOB KUHN

Title: Patent Manager, ILFORD Imaging CH GmbH

Method and Device for Curtain Coating a Moving Web

Technical Field

The present invention relates to a method and a device for coating a moving web, wherein the coating solution is applied to the moving web in a free falling curtain.

Background of the invention

During curtain coating, particularly in the case of large widths of the coating machine and at high coating speed, there are a lot of problems to apply the present coating solutions in the free falling curtain homogeneously to the moving web.

One of the difficulties is that the edges of the free falling curtain need to be stabilized, because otherwise the curtain would contract towards the center under the influence of surface tension. In order to obtain a stable curtain having the same thickness over the whole coating width, lateral guides have to be used as a rule. Different types of such lateral guides have been described for example in patent applications EP 0'281'520, EP 0'606'038, EP 0'740'197, EP 0'841'588, EP 0'907'103 and EP 1'023'949. A liquid is additionally supplied to the falling curtain at its edges in order to counteract the deceleration of the fall rate that is induced by the friction of the curtain liquid at the lateral guides. In order to adjust the desired coating width and to stabilize the edge areas formed by the impingement of the coating solution on the web, the edge areas of the curtain, guided downwards by the lateral guides, are cut off and/or sucked off by a vacuum device before the curtain impinges on the moving web.

All these methods forming the state of the art are based on the conception that a lubricating and rinsing effect has to be induced by the liquid added at the lateral guides in order to stabilize the free fall of the curtain. There is the further basic conception to separate this supplementary amount of liquid just before the curtain impinges on the moving web. All these separation devices, however, in particular the suction based devices working with small orifices, are prone to obstruction, sticking and soiling, inducing different problems during the coating process, particularly in the case where the curtain contains coating solutions that harden rapidly, are sticky or reactive and/or in the case of high coating weights.

New lateral guides are described in patent application EP 0'740'197, where the lateral flow liquid, for example water or a mixture of water and gelatin, is supplied transversely to the extension of the coating curtain as a film and where this liquid film flows downwards in a groove as a guidance face of the lateral guides. This prevents uncontrolled undulating disturbances in the curtain. There are no specific

indications in this patent application regarding the width and the surface properties of the groove best suited in practice.

An appertaining suction device is described in patent application EP 0'841'588, wherein the edge area of the curtain is removed together with the added lateral flow liquid. Without this suction device, the lateral guides described in patent application EP 0'740'197 cannot be used in regular production practice.

Summary of the Invention

It is the object of the invention to provide a method and a device for curtain coating, where the curtain falls undisturbed and a homogeneous coating with a good quality of the edges is obtained and where it is not necessary to remove the edge area of the curtain with a separation device.

This object is achieved by choosing an optimal width for the groove as guidance face in the lateral guides, an optimized surface structure of the groove and, as well, a suitable shape of the lower ends of the lateral guides.

A further object of the invention is to provide a method and a device where a homogeneous coating with a good quality of the edge is achieved without a significant loss of material under a multitude of coating conditions (speed of the moving web, coating weight, viscosity and dynamic surface tension of the coating solutions).

Short Description of the Drawings

Figure 1 shows a perspective view of a schematically depicted curtain coating installation.

Figure 2 shows a longitudinal section at the indicated position of figure 1. The sectional plane corresponds to the surface of the falling curtain.

Figure 3 shows a longitudinal section at the indicated position of figure 2.

Figure 4 shows a detailed view, in a longitudinal section, of the lower end of an edge guide at the indicated position of figure 2.

Detailed Description of the Invention

The invention is exemplified in more detail in the following drawings and examples.

As indicated schematically in figure 1, the most important parts of the coating device are the pouring plates (1) with the laterally mounted lateral limiter plates (2).

The free fall of the curtain (6) begins at the pouring lip (4) of the pouring front plate (5). Starting from this point, the curtain is stabilized by the lateral guides (7). The coating device further comprises a web (8) to be coated, which is guided around the pouring roll (9) in the indicated rotational direction and underneath the coating device.

In the coating device according to the invention, the lateral limiting liquid film (10) is supplied transversally to the curtain, as shown in figure 2. The delivery slit (12) has such a shape that the flow direction of the liquid film (11) at the exit of the delivery slit is the same as that of the falling curtain (6) in order to minimize disturbances of the speed profile.

The liquid forming the lateral limiting film consists mainly of water, which, if necessary, may contain surfactants, inorganic or organic salts, polymers, pigments or ingredients of the coating solution. It is also possible to use non-aqueous liquids for the lateral limiting liquid film.

The width L of the groove (13) in figure 3, the intrinsic guide surface of the curtain, is situated in the range between 4 mm and 11 mm, preferably between 6 mm and 9 mm. Within this range of the width of the groove (13), an optimal stability of the curtain is obtained with very small and small quantities of lateral flow liquid, as measured by the smallest amount of the coating solutions where the curtain is just not detached from the lateral guides.

The physical property of the surface of the groove (13) is of utmost importance. Rough surfaces are preferred, in particular surfaces having incorporated channels in the flow direction of the curtain, wherein the profile of the channels may be sinusoidal, triangular or rectangular or a mixture of these profiles, independently of the fact that such rough surfaces are considerably more difficult to clean than smooth surfaces. The channels are arranged in the direction of the falling curtain, either continuously or discontinuously. The distance between the individual channels is from 10 µm to 1000 µm, preferably from 100 µm to 250 µm. The depth of the channels is from 1 µm to 500 µm, preferably from 30 µm to 100 µm.

A stable coating process can be achieved with this device according to the invention with amounts of the lateral flow liquid that are below 3 l/h.

In contrast, all devices known up to now, as for example the combination of the lateral guides described in patent application EP 0'740'197 with the suction device described in patent application EP 0'841'588, need high amounts of lateral flow liquid, typically from 8 l/h to 24 l/h.

Unexpectedly, using the same coating solutions, the device according to the invention and the method according to the invention need, because of the optimized surface and width of the groove, considerably lower amounts of lateral flow liquid in comparison to the use of the known, above-mentioned device without the opti-

mized surface and width of the groove. The stability of the edge areas of the curtain at the lateral guides has been considerably improved by the optimized surface structure and width of the groove, which allows to forgo the removal of the edge areas of the curtain by a separation device.

As illustrated in figure 4, the whole amount of the coating solution together with the lateral flow liquid is applied at the lower end of the lateral guides to the moving web. In order to prevent the burble separation of the curtain from the lateral guides, the angle α needs to be between 0° and 90°, preferably between 10° und 60°.

Depending on the viscosity and the amount of the coating solutions that have to be applied, the added, mainly aqueous, lateral flow liquid at the lateral guides leads to a more or less pronounced dilution of the edge areas of the curtain, resulting in local reductions of the viscosity of the coating solutions and higher coating weights in the edge areas. Furthermore, air may be entrapped below the falling curtain, also inducing coating defects.

In order to prevent this air entrapping in the edge regions of the curtain, in particular with low coating weights and low viscosities of the coating solutions, the lower end of the laterals guides needs to have an optimal shape. The lower end of the lateral guides, directed towards the curtain, has, as illustrated in figure 4, the shape of a downward protruding edge, where the lower bezel is sharp-edged or slightly rounded. The height and, as well, the width of this edge are in the range of some millimeters. The angle β is situated in the range from 0° to 90°, values in the range from 30° to 90° are preferred.

At the lowest end of the lateral guide, the falling curtain detaches from the lateral guides and falls unguided onto the moving web situated below. In this unguided section, the curtain shows the tendency to contract due to the surface tensions of the coating solutions. This leads on the moving web to a more or less pronounced bead at the edge with all the methods of curtain coating forming the state of the art. Such beads have to be prevented as far as possible, because the higher amounts of coating solutions in these regions lead to insufficient drying, which may lead to sticking of the different loops on the wound rolls.

In order to minimize the size of the formed beads, the distance d between the protruding edges at the lower ends of the lateral guides and the moving web to be coated needs to be in the range from 0.05 mm to 3 mm, preferably from 0.4 mm to 1.5 mm, as indicated in figure 4.

Depending on the coating weights and viscosities of the coating solutions, liquids in the edge areas of the curtain (a mixture of lateral flow liquid and coating solutions) may be drawn below the elements of the lateral guides, leading to strong

soiling in the region of curtain impingement. In order to prevent this soiling, the distance d has to be adapted on one hand to the coating weights and viscosities of the coating solutions, and, on the other hand, the surface of the undersides (14) of the lateral guides needs to be hydrophobic. The free surface energy of these undersides has to be in the range of 10 mNm to 60 mNm, preferably in the range of 20 mNm to 45 mNm. Suitable surface coatings of the underside consist of amorphous carbon or Teflon. A particularly preferred coating is Teflon.

It is to be understood that the device according to the invention may be varied with respect to the indicated dimensions and may be adapted to the different working conditions encountered in practice. While each measure individually allows considerable improvements with respect to coating quality, the combination of the measures described above for the lateral guides (suitable angles α and β, optimal surface structure and width of the groove and an optimal coating of the underside (14)) results in a method and in a device, wherein separation and suction devices are no longer needed and where nevertheless the coating quality is impeccable on the moving web.

The device according to the invention shows the following considerable advantages:

- There is no need for an infrastructure for the separation systems and the drainage of the separated coating solutions.
- There are less production interruptions caused by the frequent obstruction or sticking of the sucking devices, because these trouble-prone systems are no longer needed.
- It is also possible to coat highly reactive coating solutions.

The device according to the invention will be compared in the following examples with a device representing the state of the art. However, it has to be understood that the present invention will not be restricted by these specific examples in any way.

Examples

Example 1

A first coating solution containing the ingredients of Table 1 was prepared. The quantities, with the exception of water, are those of the coated and subsequently dried layers.

Ingredient (Concentration)	Quantity (g/m^2)
Lanthanum-doped AlOOH (solid)	48.000
Lactic acid (90%)	0.780
Polyvinyl alcohol A (10.0 %)	1.440
Polyvinyl alcohol B (7.5 %)	2.880
Plasticizer 1 (40 %)	1.440
Plasticizer 2 (50 %)	0.200
Surfactant A (3 %)	0.208
Water	153.752
Total	208.700

Table 1

The Lanthanum-doped AlOOH was prepared according to the method described in example 1 of patent application EP 0'967'086. Polyvinyl alcohol A is Mowiol 26-88, polyvinyl alcohol B is Mowiol 56-98, both available from Omya AG, Oftringen, Switzerland; plasticizer 1 is 1,1,1-tris-(hydroxymethyl)-propane, available from Fluka Chemie, Buchs, Switzerland; plasticizer 2 is glycerol and surfactant A is Triton X-100, available from Christ Chemie AG, Reinach, Switzerland.

A second coating solution containing the ingredients of Table 2 was prepared. The quantities, with the exception of water, are those of the coated and subsequently dried layer.

Ingredient (Concentration)	Quantity (g/m^2)
Gelatin	11.700
Bactericide (5.88 %)	0.006
Surfactant B (10.3 %)	0.051
Surfactant C (5.26 %)	0.071
Water	60.172
Total	72.000

Table 2

The gelatin is a limed bone gelatin, available from Deutsche Gelatinefabriken, Eberbach, Germany; the bactericide is chloro-m-cresol, available from Chemia Brugg AG, Brugg, Switzerland; surfactant B is Niaproof 04, available from Fluka Chemie GmbH, Buchs, Switzerland, and surfactant C is Olin 10G, available from Arch Chemicals, Norwalk, USA.

A curtain was formed with these two coating solutions using a curtain coating device incorporating the lateral guides according to the invention. The stability of the curtain was evaluated by determining the minimal quantities of the coating solutions, for which the position of the curtain was still just stable between the lateral guides according to the invention. Water with a small addition of sodium chloride was used as lateral flow liquid. The addition of sodium chloride is necessary in order to allow the adjustment of the flow rates by magneto flows.

Results obtained with the device according to the invention are presented in Table 3. The width of the groove (13) was 7 mm, angle α was 45°, angle β was 90°, the surface structure of the groove consisted of continuous channels with a serrated profile of depth of 50 µm at a distance of 150 µm from each other.

Quantity of supplied lateral flow liquid (l/h)	Minimal quantity of coating solution 1 (l/h)	Minimal quantity of coating solution 2 (l/h)
1	63.18	43.74
1.5	38.88	25.26
2	43.74	20.40
3	68.04	34.02

Table 3

Results obtained with the device described in patent application EP 0'841'588 are presented in Table 4. In this case, the width of the groove (13) was 17 mm, angle α was 45°, angle β was 90° and the groove had a smooth surface.

Quantity of supplied lateral flow liquid (l/h)	Minimal quantity of coating solution 1 (l/h)	Minimal quantity of coating solution 2 (l/h)
6	72.90	43.74
8	53.46	37.92
16	63.18	58.32

Table 4

A comparison of the results in Tables 3 and 4 immediately shows that the minimal quantities of the two coating solutions are considerably lower with the device according to the invention in comparison to the device forming the state of the art. Furthermore, the necessary quantity of lateral flow liquid is also much lower with the lateral guides according to the invention.

Example 2

The coating solution with the composition as described in Table 1 was used.

The prepared coating solution was applied to a commercially available polyethylene coated paper support with the aid of a curtain coating device. Water with a small addition of sodium chloride was used as lateral flow liquid. The distance d between the lower end of the lateral guides and the moving web was varied in the

range between 0.4 mm and 3.0 mm. The underside of the lateral guides had a Teflon surface.

The quality of the of the edge area (beads) and of the amount of liquid entrapment (coating solution and lateral flow liquid) below the elements of the lateral guides were evaluated using the following five-grade scale:

1 (best)	regular edge, width of the bead < 3.5 mm
2	regular edge, width of the bead from 3.5mm to 5 mm
3	irregular edge, width of the bead < 5 mm
4	regular or irregular edge, width of the bead > 5 mm
5 (worst)	regular or irregular edge with separation of the curtain or air entrapment

The results obtained for the quality of the edge areas (beads) and the tendency for liquid entrapment below the lateral guides are presented in Table 5 for different distances between the lower end of the lateral guides and the moving web to be coated.

Distance between the lowest end of the lateral guides and the web (mm)	Evaluation of the edge areas and of liquid entrapment below the lateral guides
0.40	Mark 3; entrapment of liquid below the lateral guides
0.50	Mark 3; entrapment of liquid below the lateral guides from time to time with subsequent contamination
0.75	Mark 1; no entrapment of liquid below the lateral guides

Table 5

Distance between the lowest end of the lateral guides and the web (mm)	Evaluation of the edge areas and of liquid entrapment below the lateral guides
1.00	Mark 1; no entrapment of liquid below the lateral guides
1.50	Mark 2; no entrapment of liquid below the lateral guides
2.00	Mark 3; no entrapment of liquid below the lateral guides
3.00	Scale 4; no entrapment of liquid below the lateral guides

Table 5 (Continuation)

The results of Table 5 immediately show that the optimum distance between the lower end of the lateral guides and the moving web to be coated is between 0.4 mm and 1.5 mm.

Example 3

The coating solution with the composition as described in Table 2 was used. The prepared coating solution was applied to a commercially available polyethylene coated paper support with the aid of a curtain coating device. Water with a small addition of sodium chloride was used as lateral flow liquid. The distance d between the lower end of the lateral guides and the moving web was 1.0 mm. The underside of the lateral guides was coated with different materials.

The results obtained for the quality of the edge areas and the tendency for liquid entrapment below the lateral guides are presented in Table 6 for differently coated surfaces of the undersides of the lower ends of the lateral guides.

Surface coating of the underside of the lateral guides	Evaluation of liquid entrapment below the lateral guides
Stainless steel	Always entrapment of liquid below the lateral guides, approximately 5 to 10 mm, drop formation at the underside
Titanium nitride	Always entrapment of liquid below the lateral guides, approximately 5 to 10 mm, some drop formation at the underside
Amorphous carbon	Irregular entrapment of liquid below the lateral guides, approximately 3 to 8 mm, no drop formation at the underside
Teflon	No entrapment of liquid below the lateral guides

Table 6

The results in Table 6 immediately show that Teflon is an especially suitable coating of the underside (14) of the lateral guides according to the invention.

Claims:

1. Method for curtain coating a web with at least one coating solution, wherein a lateral flow liquid is supplied perpendicular to the lateral extension of the curtain and parallel to the front wall of the lateral guides to the guided curtain on both sides, characterized by the fact that the total amount of the coating solution and of the lateral flow liquid is applied to the web.

2. Method for curtain coating a web according to claim 1, characterized by the fact that the lateral flow liquid is not separated from the coating solution before the impingement on the web.

3. Method for curtain coating a web according to claim 1, characterized by the fact that the distance between the lower end of the lateral guides and the web is from 0.05 mm to 3 mm, preferably from 0.4 mm to 1.5 mm.

4. Device for carrying out the method according to claims 1 and 2, characterized by the fact that the device has not an incorporated separation device for the lateral flow liquid.

5. Device according to claim 4, characterized by the fact that the width of the groove (13) is from 4 mm to 15 mm, preferably from 6 mm to 8 mm.

6. Device according to claim 4, characterized by the fact that the angle α at the lower end of the edge guides is from 0° to 90°, preferably from 10° to 60°.

7 Device according to claim 4, characterized by the fact that the angle β at the lower end of the edge guides is from 0° to 90°, preferably from 30° to 90°.

8. Device according to claim 4, characterized by the fact that the underside (14) of the edge guide has a hydrophobic surface with a free surface energy from 10 mNm to 60 mNm, preferably from 20 mNm to 45 mNm.

9. Device according to claim 8, characterized by the fact that the underside (14) of the lateral guide is coated with Teflon.

10. Device according to claim 4, characterized by the fact that the surface of the groove (13) has incorporated channels arranged in the direction of the falling curtain.

11. Device according to claim 10, characterized by the fact that the profile of the channels is sinusoidal, triangular or rectangular or a mixture of all of these profiles.

12. Device according to claim 10, characterized by the fact that the distance between the individual channels is from 10 µm to 1000 µm, preferably from 100 µm to 250 µm, and the depth of the channels is from 1 µm to 500 µm, preferably from 30 µm to 100 µm.

Abstract

A method for curtain coating a moving web is described, wherein the total amount of the coating solutions and of the lateral flow liquid, supplied perpendicular to the lateral extension of the curtain, is applied to the moving web with formation of only a minimal bead and where there is no need to separate the lateral flow liquid before impingement on the moving web.

The corresponding device incorporates in the edge guides a groove as guiding face for the curtain, having incorporated, in its surface, channels parallel to the direction of the falling curtain. The curtain is stabilized with the lateral flow liquid which is supplied to the groove perpendicular to the lateral extension of the curtain.

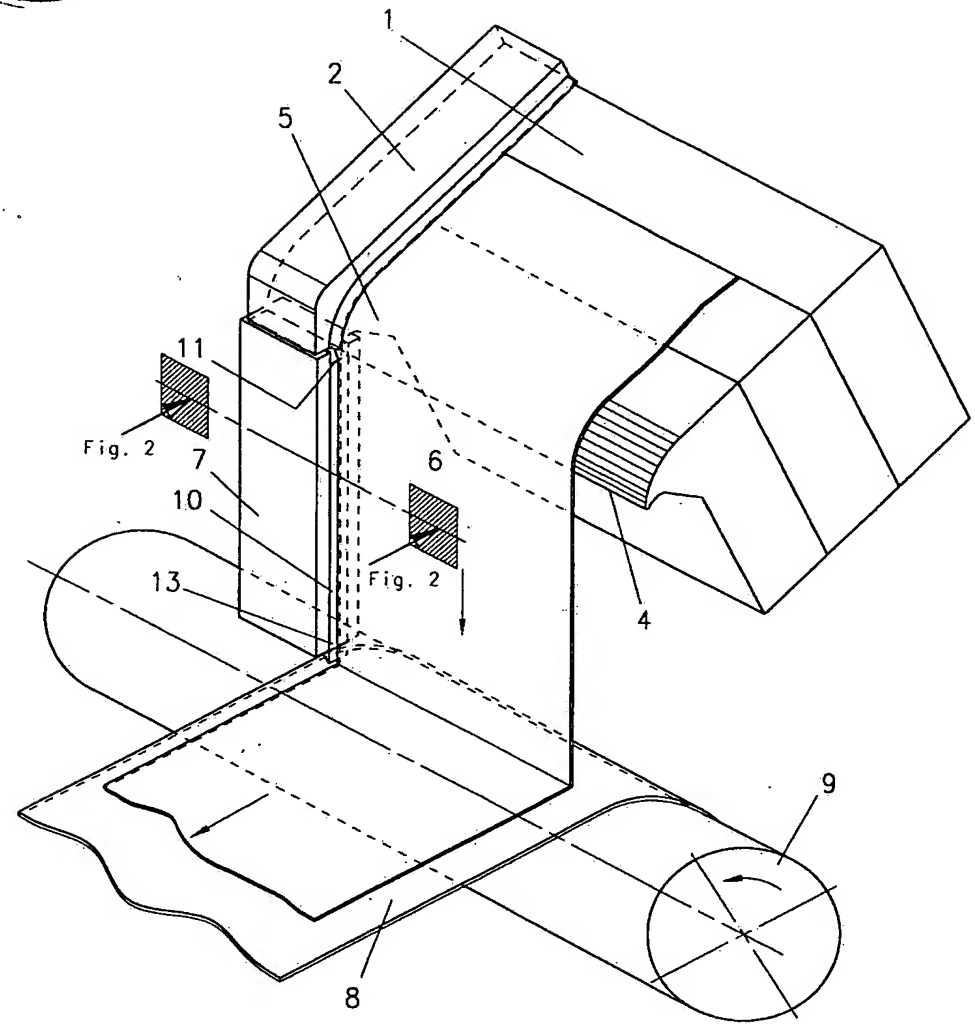

Figure 1

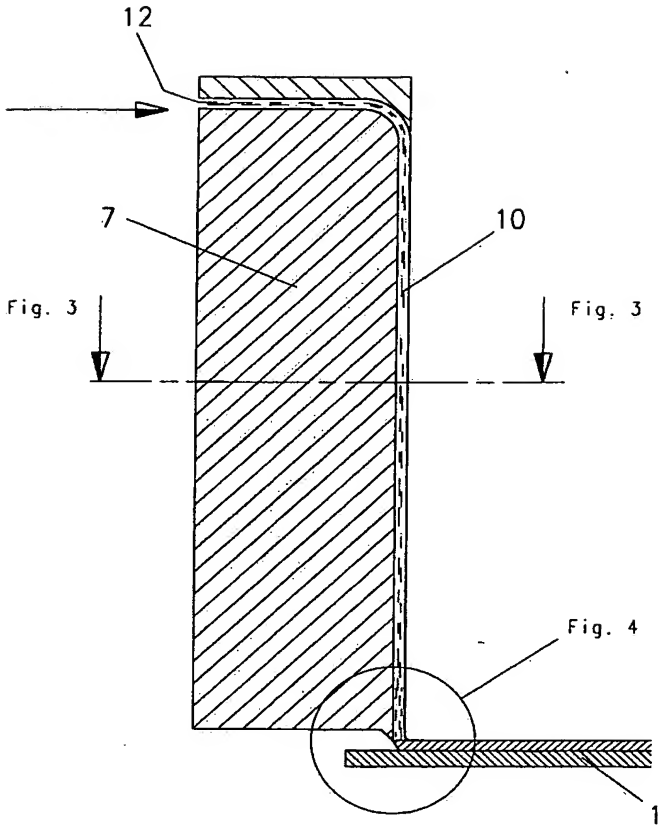

Figure 2

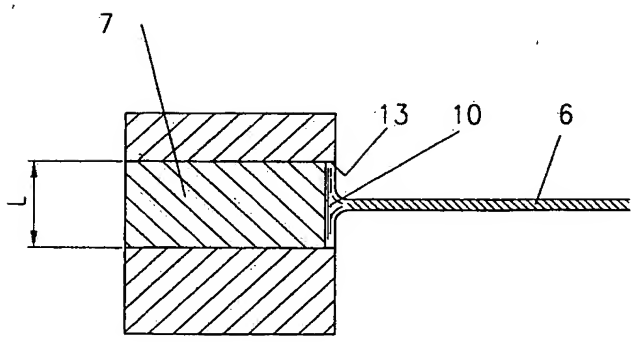

Figure 3

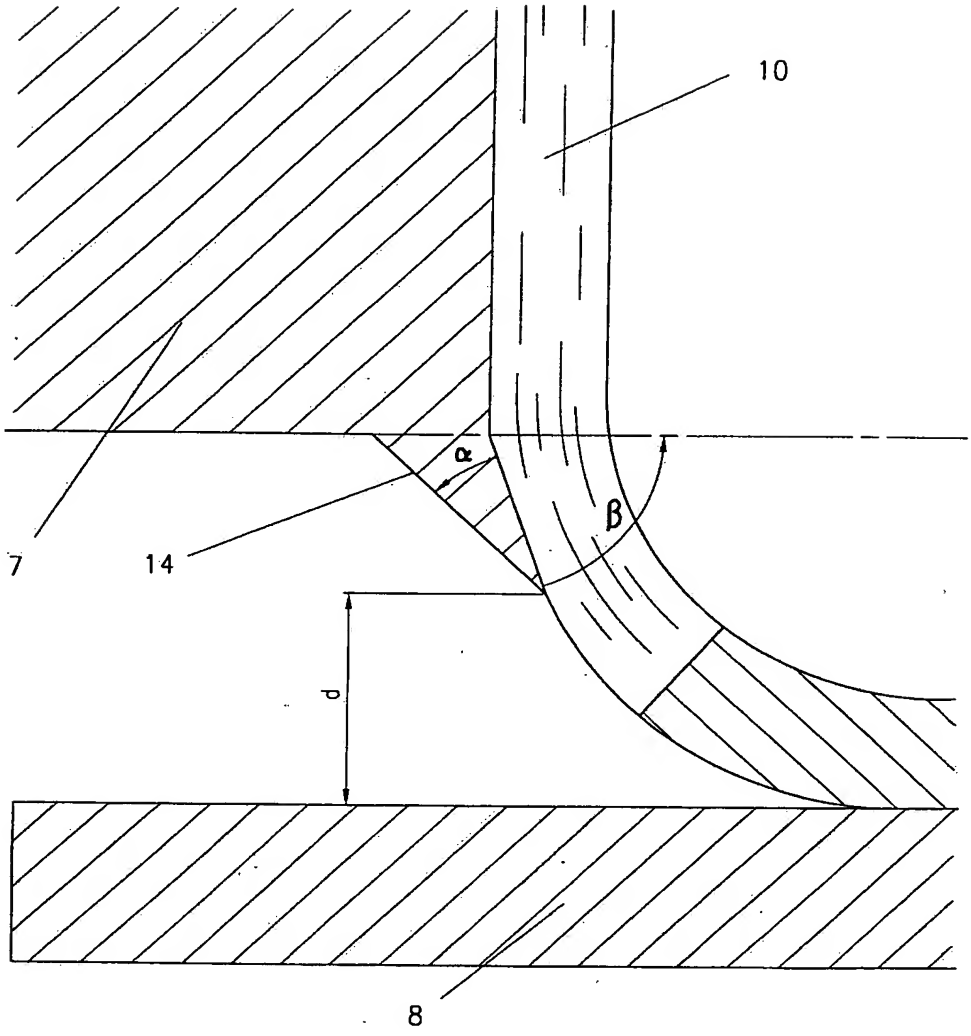

Figure 4